Nearshore Processes

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LONG-TERM GOALS

The long-term goals are to understand the transformation of surface gravity waves propagating across the nearshore to the beach, the corresponding wave-driven circulation, and the associated evolution of surfzone morphology.

OBJECTIVES

The FY01 objectives were to develop and test hypotheses for

- surface wave propagation across the shoaling region and surf zone
- surfzone turbulence, shear and infragravity waves, wave setup, and circulation
- nearshore and surfzone bathymetric evolution

Additional objectives were to

- provide data supporting other SandyDuck studies
- begin instrument tests and model development for the Nearshore Canyon Experiment

APPROACH

Our approach is to test hypotheses by comparing model predictions with waves, currents, and morphological evolution observed on natural beaches during the Duck94 (North Carolina), SandyDuck (North Carolina), XTREE (southern California), SwashX (southern California), and other field experiments.

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14. ABSTRACT

The long-term goals are to understand the transformation of surface gravity waves propagating across the nearshore to the beach, the corresponding wave-driven circulation, and the associated evolution of surfzone morphology.

15. SUBJECT TERMS

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WORK COMPLETED

Boussinesq models for directionally spread breaking and nonbreaking waves (Herbers *et al.* 2000, Herbers *et al.* in press) and spectral-refraction models for waves propagating over a pier-induced bathymetric trench (Elgar *et al.* 2001a) have been tested by comparison with field observations from Duck.

The role of fluid accelerations in onshore sand bar migration was investigated with Duck94 observations (Elgar *et al*. 2001b).

Ten-year-long time series of bed level changes at Duck were analyzed for evidence of self-organized behavior (Elgar 2001).

Infragravity motions observed with 5 alongshore arrays of current meters and pressure gages deployed for 4 months during the SandyDuck experiment were analyzed (Noyes *et al.* in press, Sheremet *et al.* submitted).

Setup and setdown measured along the main SandyDuck cross-shore transect were compared with theoretical predictions (Raubenheimer *et al.* 2001).

The accuracy of approximations to a fully quadratic bottom stress was tested with Duck94 and SandyDuck observations (Feddersen *et al.* 2000).

The effects of seafloor roughness and wave breaking on the bottom drag coefficient were investigated (Feddersen *et al.* submitted).

Nearshore turbulence levels and dissipation rates were estimated from SandyDuck observations (Trowbridge & Elgar 2001).

The performance of different flowmeters in the surf zone was evaluated (Elgar *et al.* 2001c).

Mean longshore currents predicted by a steady one-dimensional model were compared with Duck94 and COAST3D (Egmond, Netherlands) observations (Ruessink *et al.* in press).

RESULTS

Observations made along the cross-shore transect of the Duck94 experiment show that although breaking complicates wave evolution, nonlinear triad interactions are important throughout the shoaling region and the surf zone (Herbers *et al.* 2000). Wavenumbers of shoaling and surfzone waves, estimated from observations made with arrays of pressure sensors deployed in SandyDuck, agree well with Boussinesq model predictions (Herbers *et al.* in press).

Incident waves approaching the beach obliquely from the south propagated under the Duck pier before reaching the instrumented SandyDuck region. Wave energy observed near the shoreline 200 m downwave of the pier was as much as 50% lower than the energy observed 400 m downwave. Model predictions that include refraction by the bathymetric trench under the pier and partial absorption of wave energy by the pier pilings reproduce the observed alongshore gradients (Elgar *et al.* 2001a).

Simultaneous observations of waves, currents, and morphology suggest that onshore migration of the sand bar crest, observed when incident wave energy is low and mean flows are weak, is driven by asymmetrical, near-bottom fluid accelerations associated with pitched-forward shoaling waves. As the bar crest moves onshore, so does the region of strongly skewed accelerations, and feedback between waves and evolving morphology can result in continuing onshore bar migration (Elgar *et al.* 2001b).

Hurst exponents estimated from observed bed-level time series have been interpreted as demonstrating that aspects of nearshore morphology evolution are consistent with a nonlinear, self-organized process (Southgate & Möller 2000). Synthetic bed-level time series show that the observed Hurst exponents also are consistent with a linear Gaussian random process with a periodic component (Elgar 2001).

Shear waves (instabilities of the breaking-wave-driven mean alongshore current) and long gravity waves contribute to velocity fluctuations in the infragravity frequency band ($0.001 < f < 0.050$ Hz). Estimates of root-mean-square shear wave velocity fluctuations from three methods agree well (correlations >0.96), supporting the validity of their different underlying assumptions (Noyes *et al.* in press). The magnitudes of shear wave velocity fluctuations and the local mean alongshore current are highly correlated.

Seaward of the surf zone, the shoreward energy flux of long gravity waves increases in the onshore direction owing to amplification by nonlinear interactions with groups of sea and swell. In the surf zone, nonlinear phase coupling between long waves and groups of sea and swell decreases, as does the shoreward long wave energy flux, consistent with the cessation of nonlinear forcing and the increased importance of long wave dissipation. Seaward propagating long waves are not phase coupled to incident wave groups, and their energy levels suggest strong long wave reflection near the shoreline (Sheremet *et al.* submitted).

Observed setup and setdown agree well with a theoretical balance between radiation stress and pressure gradients (Raubenheimer *et al.* in press).

Several nonlinear parameterizations of a fully quadratic bottom stress are more accurate than linear approximations, and usually are adequate for nearshore circulation modeling (Feddersen *et al.* 2000).

Investigation of the bottom stress within and seaward of the surf zone over smooth and rough seafloors suggests that although bedforms affect bottom-generated turbulence and increase the drag coefficient outside the surf zone, breaking-wave-generated turbulence increases the bottom drag coefficient within the surf zone (Feddersen *et al.* submitted). However, near the outer edge of the surf zone where strong currents can smooth seafloor roughness, but breaking-wave turbulence does not reach the bottom, the bottom drag coefficient can be lower than in the inner surf zone (Trowbridge & Elgar 2001).

Observations from collocated acoustic Doppler, acoustic travel time, and electromagnetic current meters compare well with each other, demonstrating that acoustic instruments can be used to measure surfzone velocities. These observations also show systematic deviations from linear theory in the relationship between pressure fluctuations and wave-orbital velocities, and between horizontal and vertical velocity fluctuations, that may be related to the strong dissipation of surfzone waves (Elgar *et al.* 2001c).

With weak alongshore variation of incident waves and bathymetry, breaking results in a mean alongshore-directed force within the surf zone that is balanced by the drag of the mean alongshore

current on the seafloor. A model based on this balance, extended to include the effects of wave rollers and lateral mixing, agrees well with alongshore currents observed at Duck, NC and Egmond, Netherlands when the alongshore variability of the bathymetry was relatively weak (Figure 1). When the alongshore bathymetric variability increased, the model performance deteriorated (Ruessink *et al.* in press).

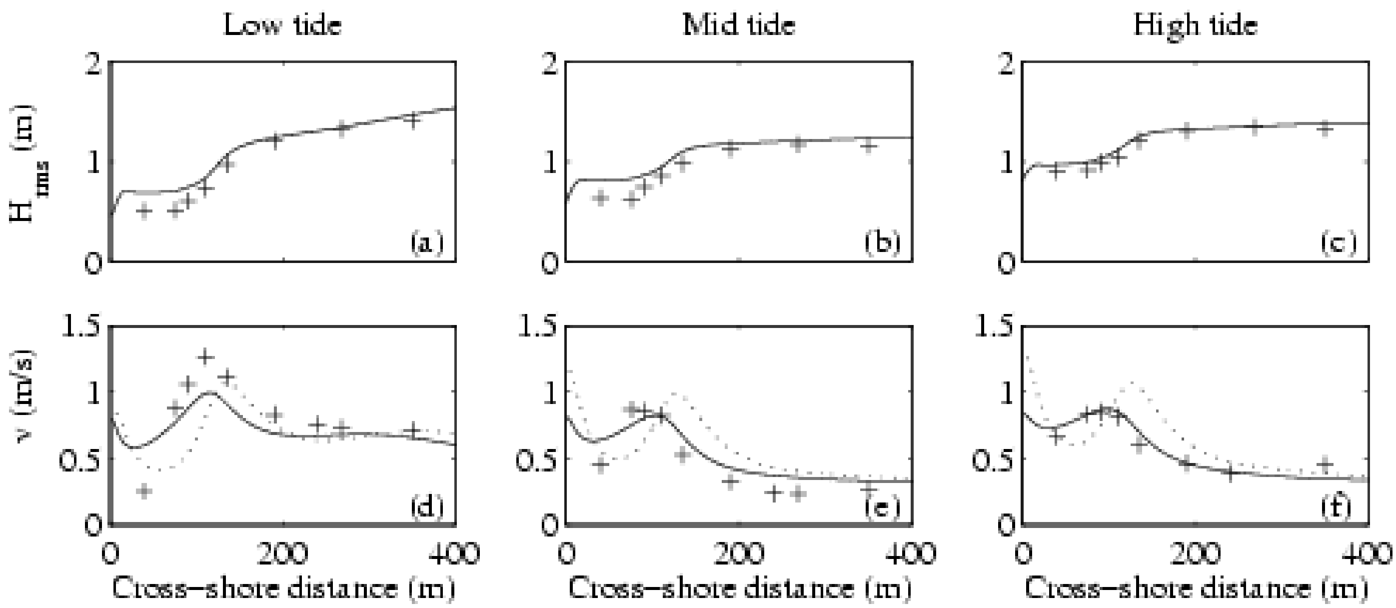

Figure 1. Measured (symbols) and modeled (curves) (a-c) wave height H_{rms}, and (d-f) mean alongshore current v (solid curves: roller, dotted: no-roller) versus cross-shore distance. Columns from left to right: low, mid, and high tide within a 12 hr period (Duck94). [The onset of wave breaking and subsequent decrease in wave height across the surf zone is predicted accurately. Models of the cross-shore variation of the mean alongshore current are improved by including wave rollers.]

A numerical model for breaking-wave-driven circulation on alongshore varying bathymetry has been developed (by graduate student K. Morris) and applied to the region onshore of Scripps and La Jolla Canyons. The circulation model, based on the steady nonlinear shallow equations, is driven by gradients of the wave radiation stress estimated using wave transformation models. Alongshore variations in wave energy and direction in 8 m depth (onshore of the canyons) predicted by a spectral-refraction model (results provided by W. O'Reilly) were used to initialize a nonlinear Boussinesq model that predicts wave radiation stresses across the surf zone (results provided by T. Herbers). The bathymetry shallower than 8 m depth was assumed to be planar (*ie,* alongshore homogeneous with no sand bars), so that all alongshore variation in the modeled circulation is owing to the effect of the offshore canyons on the incident waves. The circulation model predicts that the alongshore variations in wave forcing cause large alongshore variations in sea level and surfzone circulation (Figure 2). The planned Nearshore Canyon Experiment will acquire observations to test model predictions of the effects of offshore submarine canyons on nearshore waves and wave-driven currents.

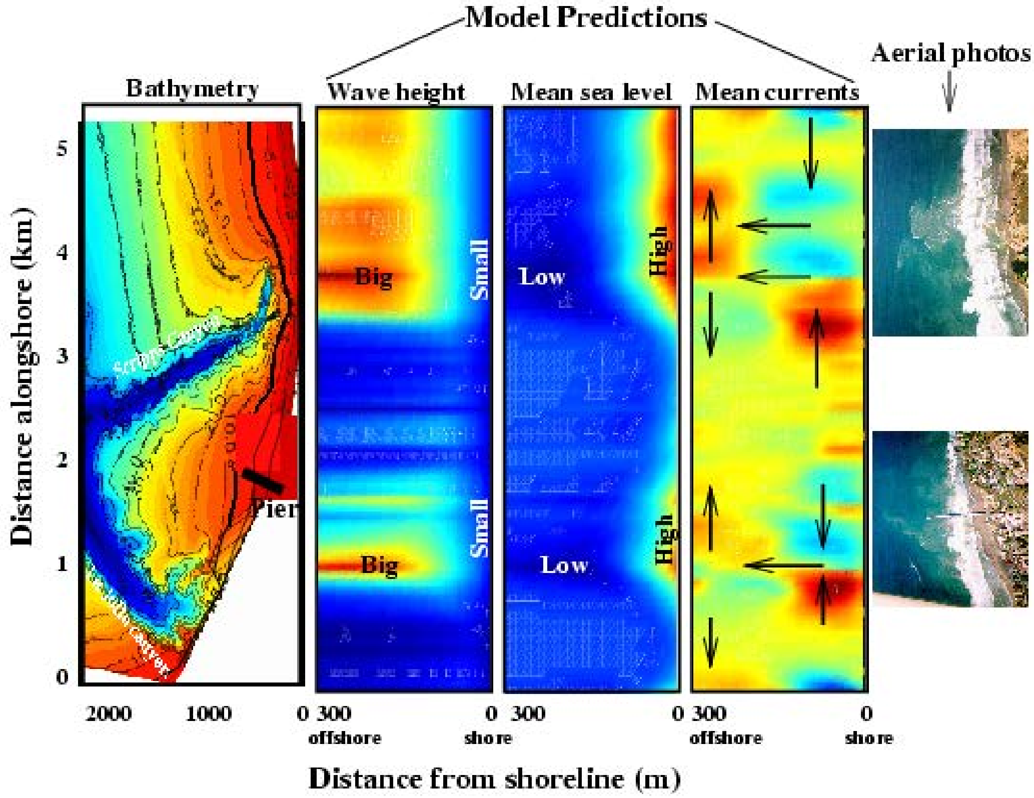

Figure 2. From left to right: Nearshore bathymetry, modeled wave height (red is large waves), modeled mean sea level (red is elevated), modeled mean alongshore current v (red and blue correspond to v with different signs, black arrows are velocity vectors), and aerial photographs of rip currents near Scripps and La Jolla Canyons. The 2 m high, 14 s swell seaward of the canyons has propagation direction 280°. [In the region onshore of the canyons, models predict strong alongshore variability in wave height, mean sea level, and circulation. The modeled circulation patters are similar to those in the photographs.]

IMPACT/APPLICATIONS

An application of the field observations is to verify and improve models for nearshore and surfzone waves, circulation, and morphological change. An impact of comparison of model predictions with observations is that mean alongshore currents on bathymetrically simple beaches can be predicted accurately given the bathymetry and incident wave conditions.

TRANSITIONS

RELATED PROJECTS

The Duck94 and SandyDuck observations of nearshore waves, currents, and bathymetry are being used to test components of the NOPP nearshore community model.

The studies of nearshore morphology are in collaboration with an Army Research Office project to investigate onshore sediment transport and sand bar migration.

Surfzone drifters are being developed in collaboration with a Sea Grant project.

We also are collaborating with other investigators, including using our measurements of waves, currents, and bathymetry in studies of bottom roughness (hydraulic drag) (Thornton, Drake), wave breaking (Lippmann), the vertical distribution of currents (Thornton, Allen), circulation (Smith, Kirby, Holland, Svendsen, Allen), the determination of bathymetry from wave data (Holland, Kirby), acoustical properties (Heitmeyer, Means), nearshore bedforms (Hay, Thornton, Gallagher), sediment transport (Miller, Resio), video estimation of surfzone currents (Holland, Holman, Lippmann), swash processes (Raubenheimer, Holland), and turbulence (Trowbridge). Additionally, during the last year we collaborated with Raubenheimer on acquiring new observations of swash zone flows (SwashX) and with Herbers and O'Reilly on modeling the effect of offshore submarine canyons on nearshore waves and currents (*eg*, Figure 2 above).

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